Context-Aware WSNs for Energy-Efficient Buildings

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Outline

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1. Smart cities as a Cyber-Physical System
   - Definitions
   - Past and ongoing projects
2. ICT for Energy efficient buildings
3. Related research topics

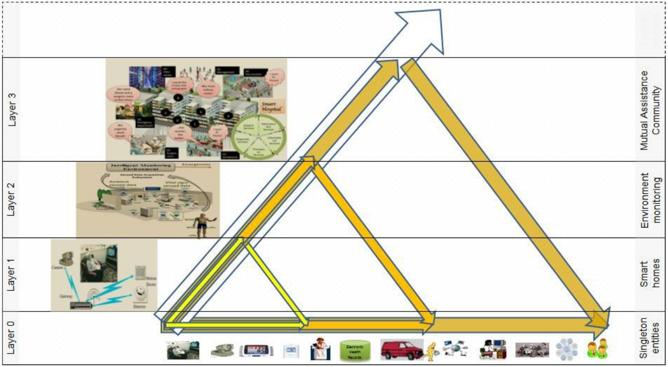
- The pervasive availability of wireless communication technologies, the emergence of GNSS infrastructures, and the deployment of handled/embedded devices allows the ubiquity and pervasiveness of services and resources
  - Ad hoc Networks are self-organizing and infrastructure-less networks: WSNs, MANETs, VANETs, PANs, BANs, WNSNs.
  - Embedded computing systems and devices have also become widespread in various application domains, as evident from their use in products such as PDAs, household appliances, and automotive systems.

M. Weiser. Hot topics: Ubiquitous computing. IEEE Computer, October 1993.

- Smart cities as a Cyber-Physical System :
  - Composed of different heterogeneous entities (e.g., individuals, groups, computers, agents, devices, services, sensing/actuating) that may join and leave the collective at any time.
  - Entities are operating at different temporal, spatial scales and social scope and interact collectively in complex manner with different objectives and goals.
  - Computational elements collectively cooperate for controlling physical entities.
  - Computational elements increasingly need to be able to collaborate and function as a part of an artificial society.

M. Bakhouya and J. Gaber, *Approaches for Ubiquitous Computing*, Wireless Ad hoc and Sensor networks, Eds. H. Labiod, ISTE Publishing Knowledge / John Wiley and Sons Inc, ISBN 978190520986, January 2008, pp, 111-142.

- CPS can be organized into several layers according to time and space scales, and of increasing levels of complexity.



- V. De Florio, M. Bakhouya, A. Coronato, G. Di Marzo, *Models and Concepts for Socio-technical Complex Systems:Towards Fractal Social Organizations*, Syst. Res. Behav. Sci. 30: 6. 750-772, 2013.
- M. Bakhouya and J. Gaber, *Approaches for Engineering Adaptive Systems in Ubiquitous and Pervasive Environments*, Journal of Reliable Intelligent Environments: Volume 1, Issue 2 (2015), Page 75-86.

Aspects of CPS	Layer 1 CPS	Layer 2 CPS	Layer 3 CPS
Heterogeneous components	Mainly artificial entities (few human input)	Human, groups of human, artificial services	Communities, networks, social organizations
Many units/nodes	Dozens	Hundreds	Thousands
Unit with conflicting objectives and goals	Unique goal (no conflict)	Independent homogeneous goals with possible conflict	Social heterogeneous conflicting goals involving arbitration
Decision-making	User centric, centralized	Multi-user centric, decentralized	Social centric, decentralized
Emergence and control	Limited emergence and full control	Limited emergence and distributed control	Emergence of unexpected phenomena and fully distributed control
Nodes may join or leave	Rarely	Commonly	Continuously
Time scale	Short term (minutes, hours)	Medium term (from days to weeks and months)	Large (months, years)
Space scale	House / Building	Buildings / City	Metropolitan / Regional
Social scope	Limited	Bounded	Unbounded

Research issues

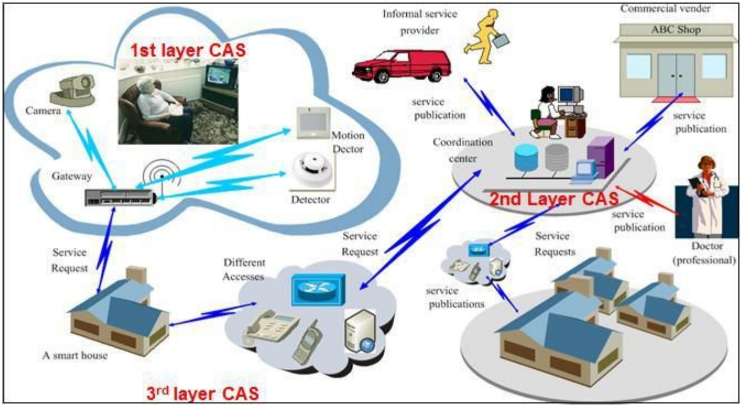
- **Operating principles by which CPS can operate**: conflicts resolution, and the need to reason in the presence of partial, noisy, out-of-date and inaccurate information.
- **Designing principles necessary to build/manage CPS**: prediction and control of the system behaviours (i.e., emergence) as well as the effect of the evolution on operating and design principles.

Requirements

- Novel principles, methods and technologies for designing and operating CPS.
- New insights into the general properties of large scale distributed systems.

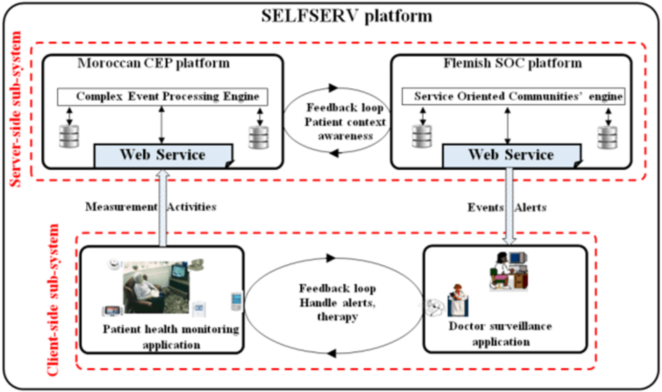
Past and ongoing projects

- Example: Mutual Assistance Community for patient monitoring



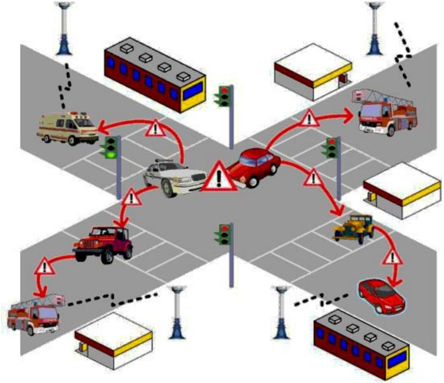
Past and ongoing projects

- SELFSERV: Platform for smarter health organization



SELFSERV project, South Initiatives programme (VLIR-UOS, 2016-2018), UMI, UIR, Antwerpen Univ, 75KEuros.

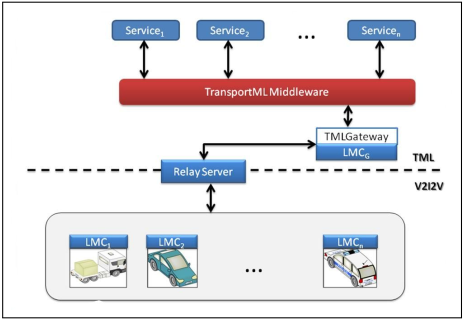
Past and ongoing projects



- ASSET (Advanced Safety and Driver Support in Efficient Road Transport, FP7-SST, 2008-2011, and TELEFOT (Field Operational Tests of Aftermarket and Nomadic Devises in Vehicles, FP7-ICT, 2008-2012, 1MEuro

Past and ongoing projects

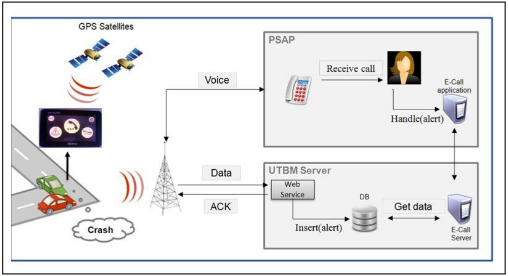
- Share information using Web services that interact to fulfil common tasks
- Results showed the effectiveness and the impact of inter-services collaboration for reducing emergency rescue time



- W. Ait-Cheik-Bihi, A. Nait-Sidi-Moh, M. Bakhouya, J. Gaber, M. Wack, *TransportML platform for collaborative Location-based services*, Service Oriented Computing and Applications, 6:4, 363-378, 2012.
- C. Dumez, M. Bakhouya, J. Gaber, M. Wack, P. Lorenz, *Model-driven approach supporting formal verification for web service composition protocols*, J. Network and Computer Applications 36(4): 1102-1115, 2013.

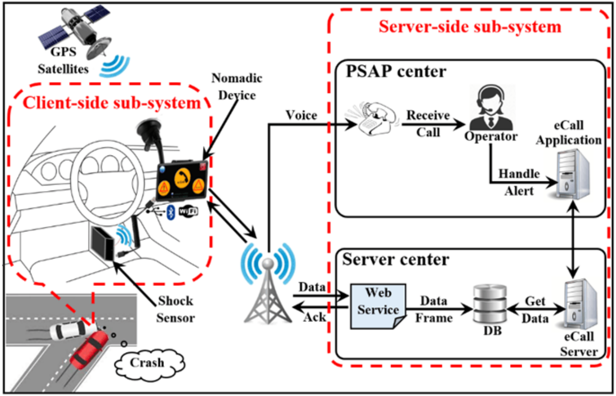
Past and ongoing projects

- A voice connection is established while sending at the same time a GPRS packet containing the geographical location of the event, a time stamp and other relevant information



W. Ait-Cheik-Bihi, A. Chariette, M. Bakhouya, A. Nait-Sidi-Moh, J. Gaber, M. Wack, *An In-vehicle Emergency Call Platform for Efficient Road Safety*, In the proceedings of the the 8th ITS European Congress, June 6-9, 2011, Lyon, France.

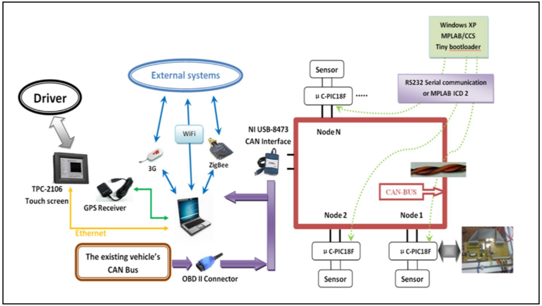
Past and ongoing projects



eCall: a Platform for Automatic Emergency Calls, submitted, Ministère de l'Equipement, du Transport et de la logistique (METL) et CNRST, 2016, UIR, UMI, UTBM, D-Sellicon Technologies, 93KEuros.

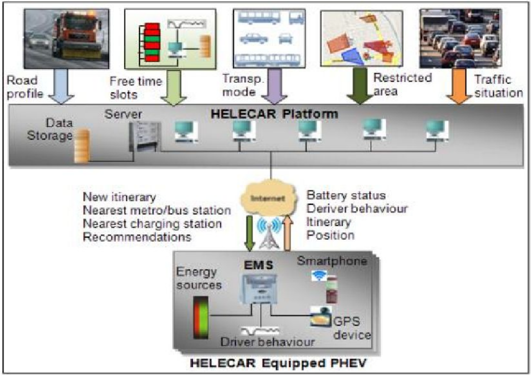
Past and ongoing projects

- Extracting, recording, and sharing information
- Involve inter-vehicle communication as a medium to exchange information



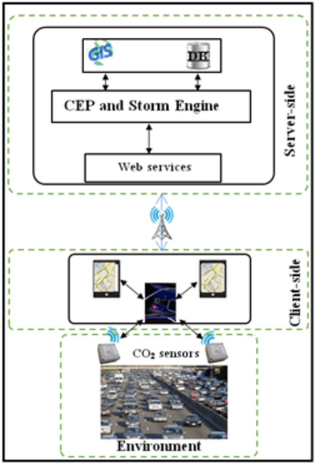
S. Cai, M. Becherif, M. Bakhouya, M. Wack, *Context Aware Embedded System for Intelligent Vehicles and Smart Roads*, ACM International Conference on Pervasive Services (ICPS'2010), 1-6, 2010.
K. Dar, M. Bakhouya, J. Gaber, M. Wack, P. Lorenz, *Wireless Communication Technologies for ITS Applications*, IEEE Communications Magazine 48: 5. 156-162, 2010.

Past and ongoing projects



SEMANTIC project, under preparation, in collaboration with PSA OpenLab France/Morocco, 2016.

Past and ongoing projects



COOMAP project, under preparation, US Middle East Partnership Initiative (MEPI), UIR and AEU, 2016.

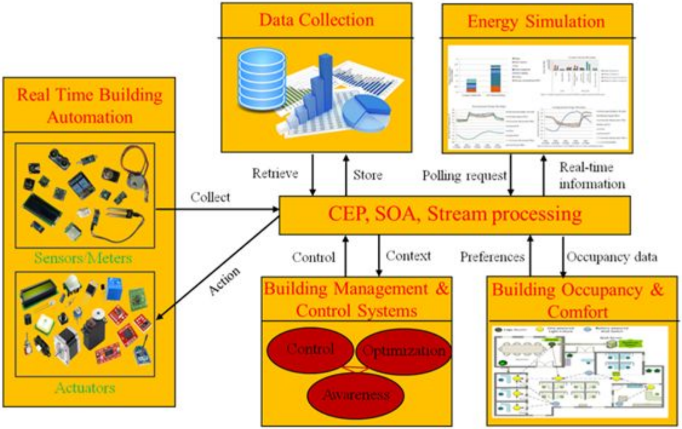
Outline

1. Smart cities as a Cyber-Physical System
2. ICT for Energy efficient buildings
   - Smart Electricity: Scenario I
   - HVAC System control: Scenario II
3. Related research topics

Energy efficient buildings

- Support energy consumption and occupant comfort by integrating ICT concepts
  - Develop intelligent WSN infrastructure that integrates heterogeneous technologies (sensors, actuators, mobile devices ..).
  - Develop energy efficient control mechanisms to improve energy efficiency.

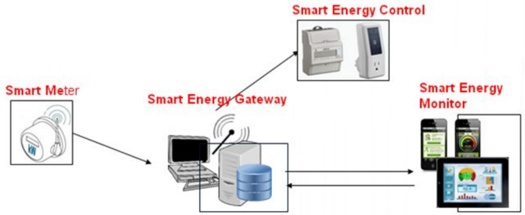
CASANET : Context-Aware Sensor-Actuator Networks for Energy-Efficient Buildings, Ministère de l'Enseignement Supérieur, de la Recherche Scientifique et de la Formation des Cadres et CNRST, 2016-2019, UIR, ENSIAS, AUI, ENSAK, UAE, Mentis, NEMPS, 89KEuros.



F. Lachhab, M. Bakhouya, R. Ouledsine, M. Essaaidi, *Approaches for Energy-efficiency and Comfort Management in Complex Real Buildings*, accepted to be considered for Nonlinear Systems and Complexity Series, Springer, 2016.

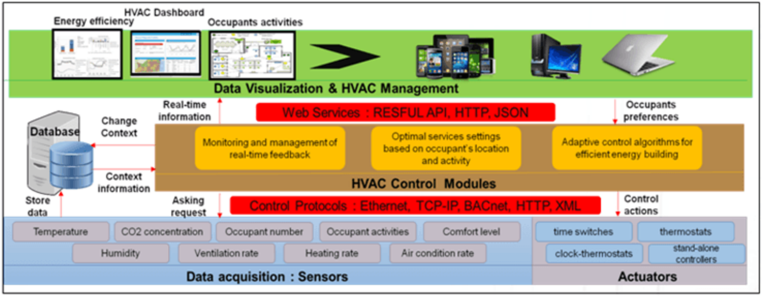
Smart Electricity

- Design and implementation of a software component that retrieves data from smart meter and make it accessible to other services.
- Incorporate a gateway that manages the recorded data and handles the requests from the smart energy monitor.
- Develop a smart phone application for providing real-time feedback of electricity consumption.
- Develop control strategies to switch on/off equipment.



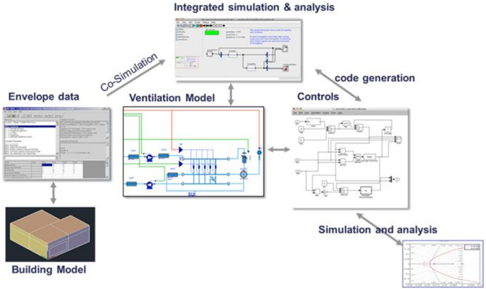
HVAC System control

- Sensing data from buildings sensors : retrieve and store data from deployed sensors.
- Pre-processing and analyzing data streams coming from different sensors.
- Propose a decision-making control methodology for electrical, heating, ventilation and cooling.



A CO2-based control

- Save 47.72% energy while maintaining comfortable indoor quality compared to the On/Off and the PI control strategies.

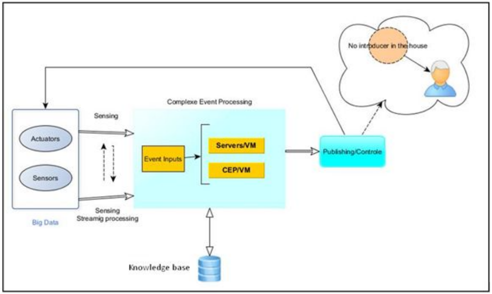


- F. Lachhab, R. Ouladsine, M. Bakhouya, M. Essaaidi, *A CO2-based Control Approach for Controlling Ventilation Systems in Energy Efficient Buildings*, to appear in IRSEC 2015. An extended version will be submitted to Energy and Building Journal, 2016.

Outline

Data processing and situation prediction

- Continuously receiving incoming real time data, while simultaneously performing high-performance processing is a challenging task.



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Data processing and situation prediction

- CEP is an approach that identifies data and application traffic as "events" of importance, correlates these events to reveal predefined patterns, and reacts to them by generating "actions" to systems, people and devices.
- SP uses software algorithms that analyzes the data in real time as it streams in to increase speed and accuracy when dealing with data handling and analysis.

Research issue

Develop and deploy a data acquisition infrastructure. The aim is to provide a software platform that allows transferring and processing data coming from different sensors in order to detect, predict, and act to contextual changes.

Data processing and situation prediction

- Combine SEP and SP from big data field for predicting events and situations in order to prevent undesirable conditions from happening
  - Save energy by adjusting control variables more efficiently.
  - The increase in the concentration of CO_2 could be predicted and the ventilation could be adjusted (e.g. full-speed) before the concentration hits a critical level.
  - Predicting outside temperatures to provide intelligent heating control.

Thank you for your attention.